On the Technique of Manufacturing

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DURING recent years there has been a growing tendency to under-estimate the importance of mechanism or system in the field of management and to assume that something more or less vague and intangible—a spirit of coöperation, democracy in industry, the acceptance of certain fundamental principles or the adoption of sound policies—meet all of the requirements and will accomplish the objects of good management. It is true that Taylor himself was wont to emphasize the importance of what he termed the "essence of Scientific Management"—the four great principles which he stated as:

> The managers assume, for instance, the burden of gathering together all of the traditional knowledge which in the past has been possessed by the workmen and then of classifying, tabulating, and reducing this knowledge to rules, laws, and formulae which are immensely helpful to the workmen in doing their daily work. In addition to developing a *science* in this way, the management take on three other types of duties which involve new and heavy burdens for themselves.
>
> These new duties are grouped under four heads:—
>
> *First.* They develop a science for each element of a man's work, which replaces the old rule-of-thumb method.
>
> *Second.* They scientifically select and then train, teach, and develop the workman, whereas in the past he chose his own work and trained himself as best he could.
>
> *Third.* They heartily coöperate with the men so as to insure all of the work being done in accordance with the principles of the science which has been developed.
>
> *Fourth.* There is an almost equal division of the work and the responsibility between the management and the workmen. The management take over all work for which they are better fitted than the workmen, while in the past almost all of the work and the greater part of the responsibility were thrown upon the men.

While we must be careful not to mistake the form for the substance, nevertheless management is a practical matter and Taylor realized that without means being provided for the intelligent, consistent and continuous application of these principles they were of no more value than would be the principles of

chemistry without a laboratory. It was he who developed step by step—not for the purpose of working out a "system," but as its necessity became pressing in his efforts to apply the principles he was evolving—a complete system of management with all of the elements coördinated and functioning as in a well built machine.

It is true and must be recognized that no one system for the application of the principles of Scientific Management can be devised that will meet the needs of all industries—nor indeed any two manufacturing establishments in the same industry. In every case the system must be designed or adapted in a greater or lesser degree to the individual business. The same raw materials or even manufactured parts may be used in the construction of widely differing products and likewise certain elements of a system designed for one business may be used with little or no change in working out a system for another and radically different business.

The planning and control of work, time study and functional foremanship (the latter, partly exercised in the shop and partly from within the planning department) comprise the principal features of the mechanism for the practical application of the principles cited.

The production of anything consists of three stages:

a. Determining *what* is to be produced—what materials are to be used and their disposition in the article to be produced. This is the function of the engineering or designing department.

b. Determining *how* it is to be produced and *when* the various steps incident to its production are to be taken. This is the function of the planning department.

c. Performing the physical work in accordance with the plans of the designing and planning departments. This is the function of the manufacturing department.

Obviously the planning department is the logical complement of the engineering or designing department. Briefly stated its functions are so to plan and control the processes of production that the personnel and the facilities of the plant, physical and financial, will be utilized to the best and fullest advantage, that the work will be done correctly and economically and that deliveries will be made on time.

In the planning department is assembled practically all of the clerical work which in a plant run under old style management

FIG. 1—THE PLANNING DEPARTMENT.

THE TABOR MANUFACTURING CO., TOOL BUILDERS, PHILADELPHIA.

1. Production clerk's and planning dept. order of work clerk's desk.
2. Typist—writing route charts, operation orders, time cards, etc.
3. Shop superintendent
5. Route clerk's desk
6. Foundry clerk (special materials clerk).
7. Balance of stores clerk
8. Clerk duplicating operation orders, time cards, inspection orders from originals written by typist (2. see above) and preparing (collating) route files.
9. Time study and instruction card desk. (Man with practical experience on right preparing instruction cards—clerk on left filling in time from tabulated data.)
11. Recording and window clerk. (Files of active route sheets back of him.)
12. Shop order of work clerk (at bulletin board.)
13. Drawing & instruction card messenger (at drawing files.)
14. } Pay roll and cost desk.
15. }

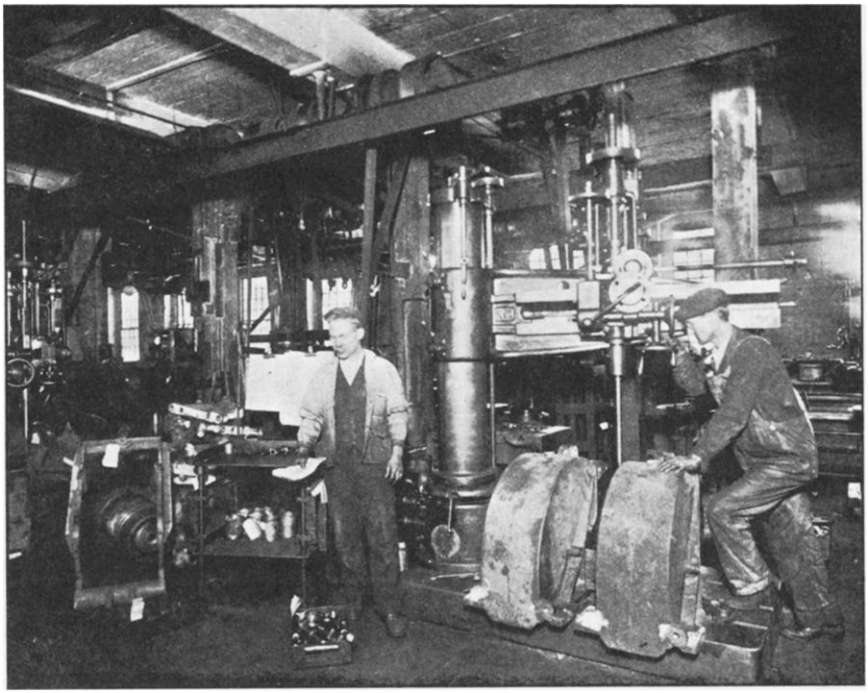

FIG. 2—FOREMAN CHECKING UP MATERIALS REQUIRED FOR THE NEXT JOB.
THE TABOR MFG. CO., TOOL BUILDERS, PHILADELPHIA, PA.

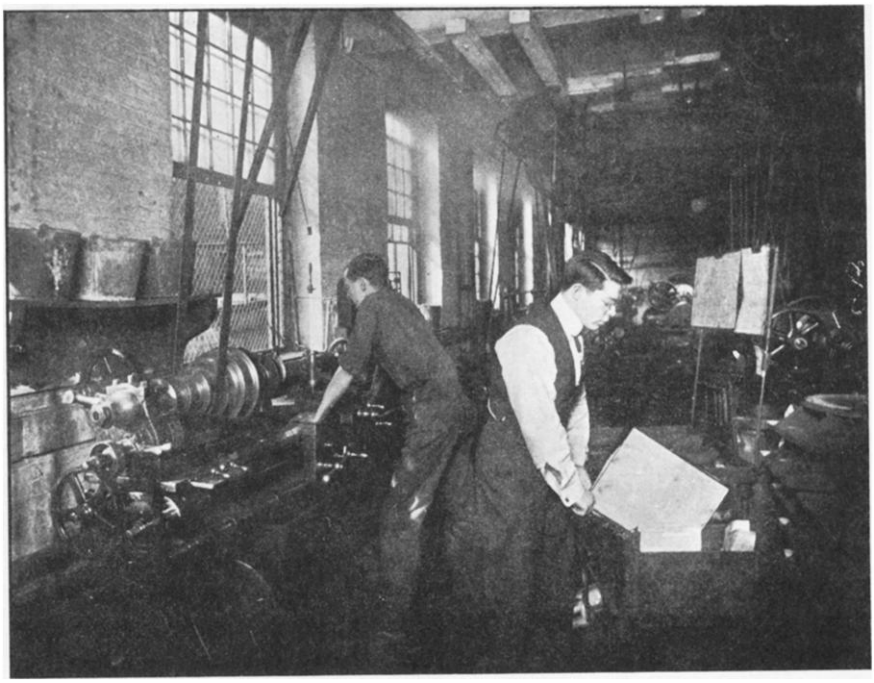

FIG. 3—DELIVERING DRAWING, TOOL LIST AND INSTRUCTION CARD TO MACHINE.
IN THE SHOP

is done here and there in the manufacturing departments, either by clerks, the foremen or even the workmen themselves. It is the repository of all data and working records required for the planning and control of work done in the plant.

The planning department should be centrally located so as to be conveniently accessible to all other departments and particularly to the manufacturing departments which it serves, the store-room and the designing (or engineering) department. In many cases it has been found desirable to install means of rapid communication between the planning department and the shop and the store-room, such as pneumatic tubes or carriers for issuing time or job cards to operators, move orders, inspection orders, instruction cards, tool lists, etc. In some instances direct telephones to various stations enabling communication without going through an exchange may be desirable.

Furniture such as will be seen in the accompanying illustrations specially designed to meet the needs of the planning department should be provided for those purposes for which experience has shown ordinary commercial office furniture to be poorly suited.

The basic data required for the planning department should include:

a. *Data relating to Product and Materials*

Drawings and bills of materials of the product (or their equivalent which in some cases may take the form of samples or patterns).

Specifications for both the product and the materials entering thereinto. This class of data should cover all of the information with respect to the product that may be needed in planning or in its manufacture.

b. *Data relating to Plant Equipment*

Complete information with respect to each machine, its capacity, speeds, adjustments, classes of work or operations to which suited, location, etc. Similar data with respect to work places other than machines, tools and appliances, etc. This class of data should be so complete that work may be planned with a full knowledge of, and in accordance with the manufacturing facilities, in such a way as to make the best use of the plant and its equipment.

c. *Elementary Time Study Data*

"Unit times" covering all of the elementary operations entering into the processes of manufacture, the adjustments and operation of machines, the use of the various tools and appliances, allowances for fatigue, for changing time cards upon the completion of each job, for inexperience of new operators, for variations in quantities, etc. In short all of the data necessary to the compilation of detailed instruction cards for any operation to be performed indicating the method to be followed and the time that the job should take under the standard conditions that have been established.

There are also built up and maintained for products that have been manufactured files of route charts or diagrams, route sheets, instruction cards and tool lists which will be described further on.

The active records of the planning department consist principally of the progress sheets (or charts) and the route sheets on which the progress on the various orders in process of manufacture is recorded and the "Balance of Stores and Worked Materials" sheets (stock ledgers or perpetual inventory) which show for each item of purchased or manufactured materials carried in stock—the quantity on hand, the quantity on order but not yet received in stores, the quantity required for (apportioned but not yet issued to) manufacturing orders or shipping orders that have been issued and the balance available for use on future orders.

It will be seen that the planning department's activities fall within three broad classes:

a. The conduct of research work, establishing and maintaining standards and the compilation of data of a basic character, applicable to the manufacture of the plant's products.

b. Planning in advance the work to be done in producing the things called for by manufacturing orders.

c. Planning and controlling through suitable mechanism, the work done in the manufacturing departments in such a manner that the plant capacity will be used to the best possible advantage, that each workman will be kept adequately supplied with work of a character for which he is qualified and that each job or order will be completed in accordance with an established order of work (or schedule) meeting the requirements with respect to time of completion and delivery.

From this point perhaps it will be best to describe the processes that take place in the planning department from the time that a manufacturing order has been issued and the necessary drawings, bills of materials, specifications or samples provided, describing each stage in the process of planning and the manner in which the work is controlled as it progresses through the shop.

ROUTING AND DUTIES OF THE ROUTE CLERK

The manufacturing order together with all data relating to design, etc., is turned over to the route clerk who plans in detail for each unit or article to be produced for the manufacturing order:

a. The quantities of each kind of material required for each different part.

b. Whether these materials are to be taken from stock on hand in the store-room or procured especially for the order.

c. Whether the part or article is something to be manufactured from material on hand or to be procured or is to be drawn from manufactured stock on hand in the store-room.

d. If the part or article is to be manufactured, the operations which must be performed in order to convert the primary material into the finished article, the sequence in which these operations must be taken up, the machine or work place best suited to the performance of each operation.

If the product called for by the manufacturing order consists of a number of parts to be assembled together after having been manufactured or drawn from the store-room, the route clerk prepares a diagram or route chart showing graphically the manner in which the various parts are to be assembled into groups or sub-assemblies and the manner in which the various groups or sub-assemblies are to be assembled to bring about the completed machine or article, the relation of the several parts and groups to each other, the relative importance of each part and group as a guide in determining the order in which the work should be prosecuted in the shop so as to have those parts requiring the greatest time to produce finished as nearly as possible simultaneously with all other parts. Likewise on the charts he shows all of the information previously described.

For each unit to be manufactured, that is to say for each part, for each group of parts to be assembled and for the assembling of the completed article, a route sheet is prepared giving the information above referred to in such a manner that the progress of the work may be recorded and regulated as it goes through the shop. He also causes to be prepared the orders on the store-room (stores issues) for the primary materials and stock parts.

It will be seen that the person performing this function must not only possess clerical ability but also be one who has had practical experience in the performance of the work being planned and that this knowledge must be supplemented by the necessary data relating to materials and manufacturing equipment. Usually he is selected from the ranks of the workmen or foremen.

Based upon the route sheets there are prepared by typists all of the orders relating to each of the several operations on each piece or assembled unit that will be required as the work progresses. These include:

a. *Move Orders* issued to men whose sole duty it is, on the orders of the planning department, to move materials from place to place in the shop.

b. *Time Cards* which are issued to the workmen at the start of each job and serve the purposes of recording progress of work on the route sheets, making up the pay roll and of cost keeping.

c. *Operation Orders* to be used in planning the work ahead for each of the machines and work places throughout the shop serving as an index to the detailed instruction cards and tool lists relating to the respective operations, indicating the machine at which the work is to be done and the time which it should take.

d. *Inspection Orders* which are issued to the inspector, in some cases for each operation, advising him of the start of each job in order that he may give the workmen such instruction as may be necessary to insure a proper understanding of the requirements as to accuracy, quality, etc., and that he may check the work up as it progresses to guard against carelessness or errors.

e. *Identification tags* to be attached to the various parts and materials.

The route sheets are attached to portfolios or to sheets of heavy paper containing a series of envelopes in which the move orders, time cards, operation orders, etc., referred to above and the instruction cards and tool lists for the various operations are placed in such a manner as to be readily accessible when wanted. The route sheets with their portfolios are later placed in suitable files indexed to facilitate finding any sheet desired.

THE BALANCE OF STORES CLERK

The next step in the planning is to send the manufacturing order accompanied by its route sheets, stores and work materials, issues, etc., to the balance of stores clerk who will make sure that adequate provision has been made for the materials required either through their being on hand in the store-room or on order. He apportions to the order the quantities of each material required, subtracting it from the quantities shown to be available on the respective balance sheets and as the balance available falls as a result of apportionment to the minimum quantity established he issues requisitions on the purchasing agent for purchased materials or issues manufacturing orders for manufac-

tured or worked material parts. Thus the stock is automatically maintained.

Later on as the material is actually withdrawn from the storeroom the balance of stores clerk also subtracts from the quantity shown to be on hand the materials issued.

The balance of stores clerk coöperates closely with the accounting department, his sheets carrying values as well as quantities are in fact details of the stores and manufactured product accounts. The minimum and ordering quantities are fixed with a view to economy in purchase and manufacture, to the maintenance of a stock which will meet the needs of manufacture without tying up more capital than is necessary and are revised as often as may be necessary to meet changing conditions.

THE SPECIAL MATERIALS CLERK

In many businesses certain materials are not regularly carried in stock, but are procured especially for the order in connection with which they are to be used. This would be the case in a machine shop with respect to castings and forgings and in almost every industry there is a similar class of material. These materials require close following up in order that they may be procured without excessive delay, and consequently it becomes the duty of the special materials clerk to requisition and follow up all materials which the route clerk has indicated as falling within this category.

TIME STUDY AND INSTRUCTION CARD MAN

The manufacturing order with its route sheets, etc., next is delivered to the time study and instruction card clerk whose duty it is to draw up for each operation an instruction card describing in detail just what the operation consists in, the method to be followed and the implements to be used, and to fill in for each one of the elementary operations making up the operation as a whole the time as shown by his elementary time study data.

The time study man in preparing an instruction card must have readily available complete information relating to each of the machines in the shop, and what tools and implements are available.

He must also have properly tabulated all of the elementary time units which may enter into work to be done. With this

data and the drawings and specifications before him giving all of the information relating to the product to be worked upon, he prepares the instruction card for each operation enumerating every elementary step which he would take if he were to perform the operation himself. Where two or more methods may be followed, if there is any question as to which is the better from the standpoint of time, he may draw up roughly a card for each. Occasionally it may be found that an operation involves some new elements calling for the making of certain studies before the time and method for the job in question may be settled upon definitely.

Simultaneously with preparing the instruction card which of course must indicate any implements to be used, a tool list specifying them is prepared, and should it be found that any new tools are required, the person preparing the instruction card must arrange for their purchase or manufacture. In short, the instruction card writer must assure himself that all of the conditions upon which he bases the method and time prescribed will exist when the work is undertaken.

Of course, it is not necessary in every instance to prepare a new instruction card for each operation on each manufacturing order passing through the planning department. Many jobs are simply repetitions for which instruction cards already exist. Frequently it is found that, while an article to be manufactured is new, some of the component parts are identical with those used in other products, or that they differ only in some degree, permitting the use of existing instruction cards with such changes as are called for by the difference in the part or article.

These cards show in summarized form the time for preparation at the start of the job, for cleaning up at the finish, the time per unit or piece, and the percentages of allowance for fatigue, inertia, etc., which may vary with the number of pieces in the lot. From this information the time for each operation is computed and entered on the time cards, operation orders and route sheets.

The time study man and the route clerk must coöperate closely with each other. The time study man is also frequently consulted by the designing department and in fact in many businesses no new article is added to the line until it has been submitted to the time study man and the cost determined on a basis of his figures as to the amount of work involved. Until active coöpera-

tion is established between the planning department and the designing department of a business it may be said that the full benefits of Scientific Management are not realized.

With the placing of the completed route sheets together with their operation orders, time cards, instruction orders, tags to be attached to the material for identification, etc., in the route files the work of planning *what is to be done* may be said to be completed and we now enter into the second stage of the planning department's activities—the planning of *when* work is to be done. This is carried on by the production clerk (sometimes called production superintendent or production manager) with certain assistants known as the planning department order of work clerk and the shop order of work clerk.

It is the function of the production clerk to see that work is completed in such time as to satisfy the needs of the sales department or in the case of stock parts, the needs of the shop. It is also his duty to see that all machines and work places in the shop are adequately supplied with work so as to keep the force continuously employed. In this matter he may be regarded as the agent of the employes and in case of any shortage of work it is up to him to bring the matter to the attention of the manager or the sales department in sufficient time to permit of taking such action as may be possible to supply the deficiency. The ultimate responsibility for keeping the shop uniformly busy and for maintaining a proper balance of the various classes of work lies with the sales department, but it is the production clerk upon whom the sales department must depend for the information necessary to accomplish this end. This the production clerk does by maintaining what is termed a "balance of work" showing the amount of work of each class ahead of the shop, sub-divided by classes of machines or operations and further by time periods. This is kept up by adding the time represented by manufacturing orders as they are entered, and subtracting as the work is performed.

In cases where the work ahead exceeds the capacity of the plant it is the duty of the production clerk to bring the matter to the attention of the manager and to follow it up and see that adequate provision is made to take care of the excess, either through the addition of equipment, working over-time or having some of the work done elsewhere.

Too much emphasis cannot be laid upon this function of the planning department. The successful outcome of the adoption of Scientific Management is largely dependent upon keeping the shop uniformly busy assuring all workers of steady employment. This is of course equally important under any form of management, but under the old type of management particularly in plants where piece work prevails—if it is realized at all—irregularity in the flow of work, dull seasons and periodic unemployment are too often regarded as conditions inherent to the business over which the management has no control and for which it feels little or no responsibility. Once a planning department has been established and is properly functioning and particularly where the task and bonus system of payment based upon time study supplants the old scheme of piece work, the condition cannot be ignored and the management's responsibilities are forcibly and continously brought to its attention.

The production clerk arranges the "order of work" or schedule indicating the order of preference to be given to each of the various manufacturing orders started out. This schedule must of course take into account the amount of work to be done and the time when the order must be finished. It serves as a guide to the planning department order of work clerk in arranging for the progress of an order through the various stages of planning and also for the shop order of work clerk in starting orders out in the shop and in laying out the work ahead for each of the machines and work places. The production clerk must each day check up the progress being made on the various manufacturing orders going through the planning department and in the shop to assure himself that his assistants are correctly following out his instructions. He must also take care of the exceptional or emergency orders coming in from time to time and instruct his assistants as to the action to be taken where things have not worked out as planned.

THE PLANNING DEPARTMENT ORDER OF WORK CLERK

While strictly speaking the planning department has no one person at its head, that is in the sense of the old time boss of a department, the planning department order of work clerk may in a certain measure be regarded as being its head. He is responsible for work proceeding through the planning department with-

FIG. 4—BULLETIN BOARDS AND ROUTE FILES.

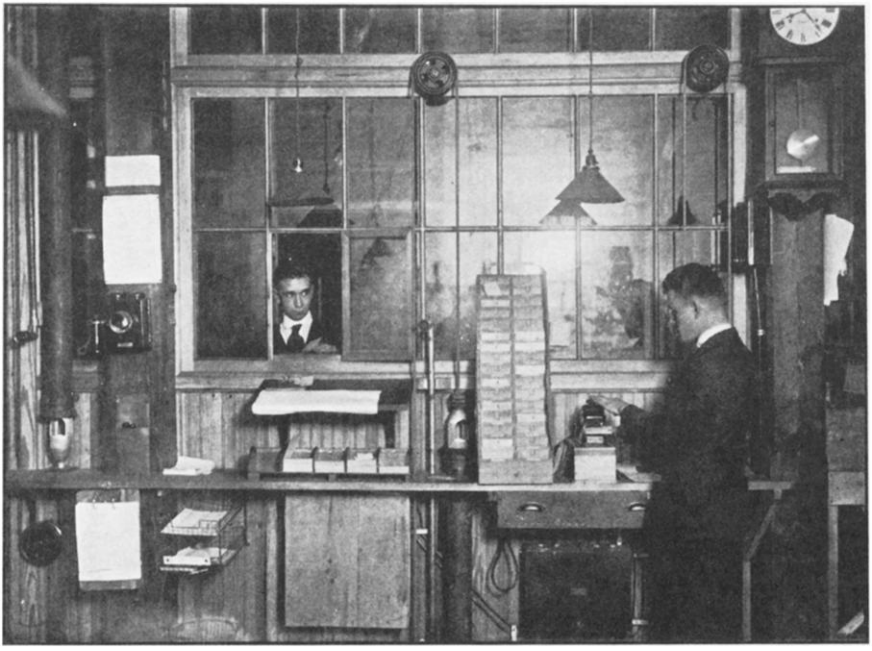

FIG. 5—WINDOW FOR CHANGING TIME CARDS, ETC.

THE PLANNING DEPARTMENT

HERRMANN, AUKAM AND CO., HANDKERCHIEF MANUFACTURERS, LEBANON, PA.

FIG. 6—A PLACE FOR EVERYTHING AND EVERYTHING IN ITS PLACE.

FIG. 7—PLANNING ROOM BULLETIN BOARD.

NOTE THE IDLE MACHINES

ROUTINE, YES; BUT NOT RED TAPE

out delay, for the work of each of the functions being kept up to date and in case of any failure to do so it lies with him to initiate and follow up such action as may be necessary to correct the trouble. Naturally he cannot be responsible for the quality of the work done by the route clerk or the time study man nor give them orders as to *how* work shall be planned, but he is responsible for seeing that these and all other functions in the planning department are adequately manned and that the personnel attend to business.

He must indicate to each of the people in the planning department the order in which they are to undertake the work ahead of them and he must advise them as to the time when each order must be completed so far as their respective part of the planning is concerned. He must maintain such records as will enable him at any time to locate any order that is going through the planning department and he must see that orders move from one planning function to another without delay. In addition to the follow up manufacturing orders going through the planning department, he must also look after the planning for the correction of any damaged or defective work reported by the inspectors as well as for the planning of any changes in work already in process.

SHOP ORDER OF WORK CLERK

The shop order of work clerk really controls the operation of the shop, the mechanism through which he does this being the bulletin board, and the route files. He has as assistants, the window clerk, who receives time cards, move orders and inspection orders as work progresses and issues to the workmen, movemen and inspectors these orders for their next jobs; the recording clerk, who upon receipt of a time card, move order or inspection order, pertaining to work that has been done indicates the progress by checking on the appropriate route sheet, removes the operation order for finished work from the bulletin board, issues through the window clerk the time cards for jobs to be started, the move orders for jobs that have been finished and inspected, inspection orders for jobs started, etc. He also has an assistant generally termed the messenger, who delivers to workmen, the drawings, specifications, samples or other information as well as instruction cards and tool lists pertaining to work ahead. (In a plant manufacturing a limited line of product where the same jobs are frequently

repeated this sort of information is maintained in the shop where it is accessible to the operators and functional foremen of the section or department to which it pertains and is not issued from the planning department for each individual job as is the case in a plant where a large variety of work infrequently repeated is done.)

On starting an order out in the shop, the shop order of work clerk arranges the operation orders for the first operations (on the parts for which material is available) on the bulletin board for the machines or work places concerned, in the order indicated by his order of work or schedule, with respect to other jobs already ahead of the machines, or work places in question. He also sees that the moving of materials as well as the work of the inspectors is controlled in accordance with the order of work and kept up to date. As jobs progress from one operation to another he arranges on the bulletin board, the operation orders for each successive step in accordance with the order of work.

Another important duty of the shop order of work clerk is to check up or to follow up through the route sheets the progress of work on all manufacturing orders, assuring himself that they are progressing at such a rate as will insure their completion in their proper order and by the time required; to bring to light any cases where the lack of materials or tools have prevented the progress of work, and above all to detect any cases where through error delays have occurred, or where the operation orders for work have not been arranged on the bulletin board in accordance with the order of work. In every instance where he finds any condition which is not right he must initiate and follow up the necessary action to correct the trouble.

He is responsible for seeing that each machine or work place is kept properly supplied with work and for bringing to the attention of the production clerk any case where there is an excess or a shortage. In cases of break-downs of machinery or anything going wrong he must see that whatever action may be necessary is taken to correct the trouble.

TIME STUDY

There is probably no branch of Scientific Management more interesting or which has been more misunderstood and misapplied than Time Study. While time study is most often thought

of as a means to determining the time in which work should be accomplished and as a basis for accurately setting piece rates or tasks, its greatest value and importance is in "the development of an art or science"—which Mr. Taylor stated as the first principle of Scientific Management. This includes effecting improvements in processes, methods, implements, machinery and materials—all essential to increasing production—establishing and maintaining for the workers such improved conditions as standards.

It was with time-study that Mr. Taylor started to develop what has since become known as the Taylor System or Scientific Management. The invention of elementary time study as a result of his efforts to set piece rates which would be fair in every respect, both to the worker and the employer, has been interestingly described by Mr. Taylor in his paper *A Piece Rate System* presented before the American Society of Mechanical Engineers in 1895.

It soon developed, however, as Mr. Taylor attempted to apply through his differential piece rate system the time studies made at Midvale that something more was required. It became evident that if the work was to be done in the time set that in every instance the workman upon finishing one job must have the material ready at his machine or his work place for his next job. To meet this need there were developed through a period of years what are now known as the routing and order of work functions and the mechanism described in the Chapter on the Planning Department.

Mr. Taylor next found that he must eliminate all causes of uncertainty as to time required to do each job, such as lay in the time it took the workmen to get together the necessary tools for each job and to grind cutting tools. He found that the tools as ground by the workmen varied greatly in their effectiveness, that is in the depths of cuts, the feeds and speeds at which they might be run. These things led to the standardization of tools used, their being kept in a tool-room from which the workman could depend upon getting without delay any tool that he might require and upon its being in first class condition. The invention of high speed steel, the Taylor-White process for its treatment, automatic tool grinders for lathe and planer tools and the slide rules perfected by Mr. Carl G. Barth were also the outcome of these efforts.

Still another source of delay which had to be overcome if the workmen might proceed with certainty of completing their work in the time set lay in the leather belts driving the machines. Mr. Taylor found that if he were to specify feed, speed and depths of cut to be taken he must establish conditions which would insure the machine being able to pull the cut prescribed and also that the workmen must be free from the annoyance and delay incident to belts breaking and having to be repaired while a job was in process. The manner in which this difficulty was overcome has been described in Mr. Taylor's *Notes on Belting*, a paper presented before the American Society of Mechanical Engineers in 1893. It was similarly found that the machines themselves must be maintained in first class condition, as they were when the time studies were made; this led to the development of a maintenance system and the establishment of the function of the repair boss, whose duty it was not only to repair breakdowns if they did occur, but as a result of periodic inspections, adjustments and minor repairs to detect and correct troubles before they had progressed far enough to cause a breakdown or to impede production.

In work of a varied nature, such as one finds in a machine shop, the various elements entering into the performance of all work may be studied one at a time independently of any particular job or operation. For example, the doing of any machine job consists of:

a. The handling of the materials, that is putting them in and out of the machine, etc.

b. The adjustments of the machine.

c. The use of implements, accessory to the machine; that is the handling of tools, putting them in and setting them, taking them out, measuring, etc.

d. The actual cutting of the metal; a mathematical problem which may be determined from tables or slide rules as described in Mr. Taylor's paper *On the Art of Cutting Metals*.

Let us suppose that we are about to make the time studies necessary to establish tasks in a machine shop.

Our first step would be to take up the machines one by one making time studies of each of the adjustments of which the machine is capable. On a lathe this would include the time for shifting the cone belt from one speed to another. We would have a skilled mechanic repeatedly shift the belt from the first to the

second cone, from the second to the third cone, etc., going through the entire range of possible changes. Starting and stopping the machine, putting in and taking out the back gear, moving the carriage from one position to another, moving the cross slide in or out, would each be studied in turn. So we would go through all of the possible adjustments, the workmen repeating each adjustment a sufficient number of times to establish the standard elementary time unit.

Having equipped our tool room with standard tools we would take each tool in turn and make a study of all of the uses to which it might be put. For example, in connection with twist drills we would study the time necessary to select from an assortment of drills such as would be provided for a job, a drill of a given size, to put this drill in the spindle of the machine, the time to remove the drill from the spindle and place it back on the tool stand. This would be repeated a sufficient number of times in connection with each size and kind of drill.

In making studies of this sort many causes of delay or uncertainty as to the time required for an elementary operation would develop. For example, it was found in making studies of the handling time for twist drills that it required a greater amount of time for the workman to assure himself that he had a drill of the size called for than it did to perform all of the rest of the elementary operation. This was due to the fact that the makers stamped the size on the drills in small, difficultly read figures placed upside down so that they must be read with the shank toward the workman, necessitating his turning the drill first to read the size and again to bring it in position for placing in the spindle. To remedy this the practice was established of filing a flat spot on the shank of every drill, on which was stamped the size in large, easily read figures, with the result that irregularity in the time required to select the drill and verify the size was eliminated and considerable saving in time effected. It is in the great multiplicity of little savings such as this that lie the gains effected as a result of time study.

The time for handling materials in machine shop work presents greater difficulty in its determination and tabulation owing to the great variety of shapes, volumes and weights of castings and forgings, but reasonably accurate figures may be established.

The importance and difficulty attending tabulation of the elementary time study data in such a manner as to make it available and directly applicable in establishing the time for any new job that may come along is perhaps greater than is generally realized. It is perhaps more difficult than the making of the studies. While in an engine lathe an infinite number of different jobs may be done, they all consist of different combinations of identical elementary operations. For example, the speed must be changed perhaps several times. On a given machine it will take the same time to change from the first speed to the second speed, no matter what the job may be. In the case of work carried on centers in almost every job a carrier or dog must be put on. For the same size carrier (assuming it is in first class condition), the time will be the same no matter what the job may be. The putting in and taking out of cutting tools is the same for a given tool irrespective of what the job may be; the time taken to set a pair of calipers and to try the size of the work will be the same for a given diameter no matter what the job is.

In order to make the time study data applicable to the entire range of work which may be done in the shop and to any new work which may be undertaken, the studies of the handling time relating specifically to the machines are tabulated, classified and indexed under the symbols and numbers of the machines to which they apply. The studies of the handling time relating to tools or implements are tabulated, classified and indexed under the symbols and sizes of the tools to which they pertain, and so on. In making up instruction cards the time for the various elements is selected from the tabulated elementary time units.

In the same way handling time for the simpler industries must be taken in elementary form and so tabulated and indexed as to make it available for the establishment of the task time on any new style or size of product that may be introduced. An essay consists of the twenty six letters of the alphabet combined to form words and the words combined to form sentences. Elementary operations (units) are comparable to the letters of the alphabet, small groups of elements frequently used together are comparable to words and the combinations making up a job to sentences and paragraphs.

In the simpler repetitive industries of which the manufacture of handkerchiefs is typical, where an operator performs a single elementary operation repeatedly, the studies are usually made of the cycles of elements comprised in the performance of each operation.

The importance of time study in the development of an art or science—and an art or science may be developed in even the simplest kind of work—is brought out by the following typical illustration describing an effort to establish the task and bonus time for machine ironing handkerchiefs. It was easy enough to determine the time necessary for picking up a dampened handkerchief and passing it through the mangle, but it was found that in some cases a handkerchief would be properly finished with a single pass while in others it required two or even three passes before it came out properly ironed and finished. The causes for this irregularity lay partially in the fact that the several machines varied as much as thirty per cent in the speed at which they ran and that the pressure of the steam used for heating the mangles varied greatly from time to time during the day and consequently the temperature of the drum varied. There were also imperfections in the material wrapped around the drum. The greatest cause of irregularity, however, lay in the fact that the handkerchiefs were not uniformly dampened, one method of dampening being to hold them in a fine spray of water in a tub; the length of time they were held in the spray being a matter for the operator's judgment. Another method was to soak a long strip of cotton cloth in water, wring it out by hand and then place the handkerchiefs in packs of one dozen between folds of the dampened cloth, permitting them to remain until the moisture had diffused itself throughout the entire pack.

Investigation showed that the secret of success lay in first putting into the handkerchiefs the *right amount* of water, for which a special machine was developed; second, permitting them to stand in an air-tight closet long enough to diffuse the water evenly through each handkerchief; third, not permitting them to stand long enough before ironing to give off an amount of this water which would result in imperfect ironing. These factors were determined for each kind, weave and finish of cloth by experiments extending over several months.

In connection with this operation it was also found that in the former practice of having one girl continuously feed the handkerchiefs into the machine with a less skilled and lower paid assistant on the other side receiving and placing them in piles, the operators could not accomplish their tasks with any degree of regularity. The reason was that the feeding of the handkerchiefs was much more trying and more difficult than the receiving and piling, as the operator had to stand continuously close to the hot drum of the machine, while the operator on the other side might sit down not so close to the heat. Consequently while an operator might for a certain period of time easily feed handkerchiefs at the rate shown to be possible by the time studies, if she kept at it continuously her production fell off. This was remedied through teaching the operators who formerly did nothing but receive and pile the handkerchiefs the operation of feeding and having the operators change off, the feeder becoming the receiver and vice versa, at sufficiently frequent intervals. This made it easier for the girl who had formerly been feeder and enabled the girl who had formerly been the receiver to earn higher pay. Production was more than doubled. Many similar instances might be cited to illustrate the sort of development that comes when real elementary time study is undertaken.

From the foregoing it will be seen that it is a relatively simple matter for a man skilled in the trade or industry in question, having before him the drawings, specifications or samples of a new job which has never been manufactured in the plant, first to write out a list of all of the elementary operations which go to make up each major operation in the manufacture of the product, and having done this, to select from his time study data the time for each of the elements involved in each operation; and thus to set for a new job the time which it should take just as accurately as might be done for any job which had been previously done in the shop.

For the making of time studies a decimal stop watch which not only may be snapped back and permitted to start from zero with a single pressure of the finger, but which also may be stopped at any point and started again from that point, is necessary. The ordinary type of stop watch or horse time is not at all suitable. A board designed to hold the stop watch in a convenient position

and also to hold the sheets of paper on which the time study man records his observations is necessary.

In starting to make a time study, before the watch is used, all preparation should be made, the provision of materials, tools, etc., and the conditions generally made as perfect as possible. Usually it will be found simply by observation that a great many things are wrong with the process, the implements and the equipment in general as the work has been previously done, which must be corrected.

The time study man must thoroughly explain to the operator the purpose for which the studies are being made, something of the theory of time study, and secure the interested coöperation of the worker in the undertaking. The operator's part in making time studies and in the resulting improvement in methods, conditions, etc., is in many respects just as important as that of the time study man, and naturally the operator selected to coöperate in the making of time studies should be a first class operator, that is one who is above the average, but not an exceptionally fast operator.

The next step is to make a list, in their proper sequence, of the elementary operations to be studied. This may be done while the operator is going through the sequence two or three times before the time is taken and entered on the sheet. From there on the time study should be made with the watch running, the time study man noting on his sheet the reading of the watch at the completion of each elementary operation. Any unnecessary delays, false moves, or difficulties encountered and the time they involve must be noted. The time study will show up various difficulties which must be overcome or conditions which must be improved if the operator is to perform the same elementary operation repeatedly in the same time. For example, in studying the folding of handkerchiefs preparatory to their being pressed, tied and boxed, it was found that a considerable number of handkerchiefs were not square and whenever a crooked handkerchief was found the operator had to straighten it by pulling on diagonally opposite corners. It was also found that the operators had a habit after having folded a handkerchief of patting it from two to ten times with the hand for the purpose of creasing or setting the fold. To correct the crookedness of the handkerchiefs neces-

sitated going all the way back to the cutting and hemstitching operations at the start of the process. The time lost in unnecessarily patting the handkerchief was overcome by getting the operators out of the habit and teaching them to crease the fold with a single movement of the hand.

After a sufficient number of observations have been made and all of the difficulties noted and overcome, the standard elementary time unit is selected for each of the elementary operations. There are a number of methods used, all more or less intricate, in selecting the standard elementary time unit, but the simplest and one which has proved to be eminently satisfactory, is to select that time which occurs most frequently in a series of observations. If there is any difficulty in this it indicates something wrong with the conditions or the study. In the case of operations such as folding handkerchiefs it will be found that many of the elements consume less than one hundredth of a minute. A skilled time study man may record a sequence of elements of about two hundredths of a minute each in duration, the limiting factor being the speed with which he can enter the time on his observation sheet, and while by direct reading an occasional element as small as one hundredth of a minute may be taken, it is impracticable to do so if a large proportion of the elements are so small. To overcome this difficulty Mr. Carl G. Barth has developed a very simple method.[1]

In setting tasks based upon elementary time study, not only must the time for each elementary unit be included, but there must also be an additional allowance made to cover fatigue, mental inertia or the unavoidable pause between the completion of one elementary operation and the starting of another, which might perhaps be defined as the time required to think what is next to be done and for the mind to telegraph its orders to the hand; and also to cover the time which should be provided for the operator's own needs.

In repetitive work the determination of the percentage of allowances is relatively simple, the usual method being after the time for a given operation has been determined to make an overall study ranging from one to three days in duration, noting the time taken for the completion of each cycle, all delays, false moves, etc.

[1] Taylor, F. W., *Shop Management* pp. 172–174. Harper Edition.

After eliminating any unnecessary delays the difference between the overall time for the work done and the time as shown by the time study gives the percentage of time which must be added to the flat or minimum time. In work of a more varied nature it is not so simple as the time allowance varies in proportion to the number of different elements entering into a job and the frequency or infrequency with which they are repeated. For example, a simple job consisting of a small number of elements repeated over and over again becomes largely mechanical and calls for a very small percentage of extra allowance, say about fifteen per cent, whereas a complicated job consisting of a large number of different elements, the complete cycle to be performed only once may call for an allowance as high as one hundred per-cent of the flat or minimum time. In every plant formulae for the percentages of allowance must be established as a result of study.

The time study man himself should be one who has had extensive experience in the work to be studied and it is desirable, and in some industries necessary, that he be able personally to perform any of the operations which he may study. He should be a person of mature age and possess infinite tact and patience, being able to get along well with the workers, to command their respect, and of a character and personality which will assure the workers of his fairness and his interest in their welfare. He must also be of a scientific turn of mind, be able to analyze the work to be done and possess the requisite ingenuity and energy and perseverance for correcting improper conditions and for effecting improvements, the need for which his analysis and study will bring to light.

The time study man's function does not cease with the establishment of a method and the time which work should take, but what is of greater importance is that he follow up his work to make sure that the method once established is adhered to, and that the conditions upon which the performance of the work in the time set depend are maintained. He must investigate or have investigated by one of his assistants every case of failure to earn bonus, to determine whether or not such failure is the fault of the operator or due to conditions over which the operator has no control. In all cases where it is found that the failure to earn bonus is due to some causes beyond the control of the oper-

ator he must see that the time is adjusted accordingly in the operator's favor. He must be equally firm, however, in seeing that the bonus is not paid to an operator where the failure to accomplish the job on time is due to something for which the operator is responsible, such for example as a deviation from the method or carelessness.

The importance of having detailed instruction cards, which may be referred to by the functional foremen and the operators, not only to show what the time allowed for each job is based upon, thus inspiring confidence, but as a means to the maintenance of the methods and standards established, will be apparent.

FUNCTIONAL FOREMEN IN THE SHOP

In place of the single foreman in charge of a shop or a department or section thereof having to perform all of the duties in conjunction with its operation—such as increasing or decreasing his force of employes, keeping them supplied with work, correcting troubles, looking after the repairs and in general supervising all of the thousand and one things incident to the operation of the shop—we have under Scientific Management several foremen, each performing a single specific function. Certain of these functional foremen as has been shown are located in the planning department. Among them are the route clerk who plans the method to be followed in performing the work, the time study and instruction card man who plans in further detail just how each operation shall be done and sets the time, the order of work clerk who sees that each workman is kept supplied with sufficient work ahead, and that the jobs are taken up in proper sequence, etc. In the shop proper there are usually four functional foremen who come directly in contact with the worker. Each of these will be described in turn.

The *gang boss* is responsible for checking up and seeing that all preparation for each job has been made in advance, that materials and tools and instructions have been delivered and are located conveniently for the operators to whom the jobs have been assigned; in this he supervises the work of the move-men and others who serve the worker. He is responsible for the orderliness and cleanliness of that section of the shop under his charge and for seeing that the workers lose no time between jobs. He

also, in many industries where the setting up or changing of a machine is necessary before proceeding on a new job, assists and instructs the operator in this part of the work.

The *instructor* is responsible for seeing that the methods prescribed by the instruction cards are followed and for giving such help and instruction as may be required to the less skilled operators. As a matter of fact a great number of the operators require little if any assistance from the instructor as a regular thing, so that his attention is in a large measure confined to the newer operators or those who have difficulty in accomplishing their work in the time set. The instructors also act as the agents of the time study man—investigating failures to accomplish work in the time set, reporting any difficulties encountered calling for correction or adjustment, checking up the standard methods and conditions established to guard against retrogression.

The functional foremen previously referred to are primarily concerned with matters of production. It is their duty to see that the work is turned out in the time established and to see that any conditions which interfere with production are corrected. On the other hand it is equally important that the work produced shall be up to the required standard with respect to quality. It is obvious that people who are primarily interested in production will not be equally interested in quality and vice versa. Therefore it is the practice to have in each section of the plant a functional foreman known as *the inspector*, whose duty it is to see that the work turned out is up to the required standard of quality and who has no interest whatever in the speed with which it is done. The inspectors are in effect instructors in quality.

Good inspection *prevents* spoilage or bad work instead of *detecting* it. The customary method of inspection is, for the planning department, when a job is started to send a notice to the inspector advising him to that effect. The inspector goes at once to the work place, gives the operator such instruction or explanation as may be necessary and sees that the first piece or the first few pieces produced are correct. He returns from time to time during the process of the operation inspecting the work which has been completed since his last visit, so that by the time the job is finished he has inspected all of the work turned out. He then reports to the planning department the results of his

inspection, reporting any damaged or defective work and the nature of damage or defect. It must be borne in mind that the bonus, or the high rate in the case of differential piece work, is paid not only on condition that the work be accomplished in the time set, *but that it shall also be in accordance with the requirements as to quality.* The inspector is usually responsible directly to a head inspector who in turn is responsible to the Designing Department and has full authority to reject any work not up to the standards.

The repair boss under the scheme of functional foremanship is responsible for the condition of the machinery and appliances throughout the shop, for their being kept up to the standards which existed or were established at the time the elementary time studies were made and for guarding against breakdowns due to neglect. He also instructs the workmen in the proper care of their machines and sees that they are not damaged through carelessness or abuse. In a small shop the repair boss with occasional assistance may personally perform all of the duties in conjunction with this function, while in a large plant he may have a considerable organization including a repair shop of his own and may carry out his duties through rather an elaborate system such as the writer described in a paper presented a few years ago before the Taylor Society. In a large plant the repair boss might be dignified by the title of Superintendent of Maintenance. The feature of this work to be emphasized is that breakdowns and the necessities for emergency repairs should be prevented through adequate periodic inspection and adjustment of machines and appliances.

Happily the old idea that good management consisted in keeping down what was often erroneously termed "non-productive" expense is on the wane, as is its twin fallacy the belief that the payment of low wages was essential to low manufacturing cost, and with them are passing the objections of the manager of the old school to the newer and more effective way of doing things.

The absurdity of constructing a subway, an office building or building a machine for any purpose without complete engineering plans and specifications is today apparent even to the non-technical public. Yet it is within the memory of living men that a draughting room, an engineering department or a designing

department was regarded as "non-productive" and even undesirable, while today it is a recognized necessity; the planning department is steadily and rapidly coming to be generally regarded in the same light. With the planning and control of work as has been described taken care of in the planning department, the foremen—each specializing on a given function—are enabled to devote their entire time to supervision of work in process, instructing and helping the workmen and straightening out with a minimum of delay and friction those things which will go wrong in spite of the best of planning. The workman benefits as a result of the better service he receives and is saved much time and annoyance in procuring the information he must have before proceeding with each new job, figuring out the method and getting together the tools and materials required.

Assuming that all workmen were of equal ability in these matters (which unfortunately is not the case) and that each workman were fully as competent as those selected men who under Scientific Management specialize upon the planning, still there would be a great advantage in doing it in the planning department where it is done in advance (instead of, as is inevitable in the shop, hastily at the start of the job or during its progress), in an environment better suited than that of the shop itself, and with all necessary and helpful data readily available. Furthermore *while the planning is being done the workman and the machine are engaged in actually turning out product.*

Under true Scientific Management through the planning department and the functional foremen in the shop every effort is made to place at the disposal of all workmen the best knowledge relating to the processes, to supplant loose opinion with demonstrated fact, to develop to the fullest degree the skill and intelligence of every workman, and to create conditions that will enable him easily to turn out much more work for the same expenditure of time and effort than would be possible under the old way of doing things. Thus he can make higher wages without increasing the cost, and through the elimination of annoyances and obstacles, be happier and healthier while doing it.

Secretary Wilson expressed himself recently as follows in addressing a meeting of Governors and Mayors:

> Employers and employees have a mutual interest—not an identical interest, mark you, but a mutual interest, in securing the largest amount of production

from a given amount of labor, having due regard to the health, safety, opportunities for rest, recreation and development of the workers; for if there is nothing produced, there will be nothing to divide; if there is a large amount produced, there will be a large amount to divide; and the interest of the employer and employee only diverge when it comes to a division of that which has been mutually produced, and if they are wise in their generation, when that divergence takes place, they will sit down around a council table and endeavor to work out the problem on as fully a just basis as the circumstances surrounding the industry will permit.

Sentiments such as this show a recognition of the needs of society and also indicate the need of a plan—definite, consistent and workable. Taylor years ago foresaw the needs, expressed the same truth, and devoted his life to the development of the plan to meet the needs which the writer has described.